

**МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ**  
**НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ**  
Кафедра конструкції літальних апаратів

**«ДОПУСТИТИ ДО ЗАХИСТУ»**

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**ДИПЛОМНА РОБОТА**  
**ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ «БАКАЛАВР»**  
**ЗІ СПЕЦІАЛЬНОСТІ**  
**«АВІАЦІЙНА ТА РАКЕТНО-КОСМІЧНА ТЕХНІКА»**

**Тема: «Аванпроект дальньоньомагістрального пасажирського літака**  
**місткістю 240 пасажирів»**

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**Київ 2022**

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NATIONAL AVIATION UNIVERSITY  
Department of Aircraft Design**

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«\_\_\_» \_\_\_\_\_ 2022

**BACHELOR DEGREE THESIS  
ON SPECIALTY  
"AVIATION AND AEROSPACE TECHNOLOGIES"**

**Topic: "Preliminary design of the long-range passenger aircraft with 240  
passengers capacity"**

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**Kyiv 2022**

# НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Аерокосмічний факультет  
Кафедра конструкції літальних апаратів  
Освітній ступінь «Бакалавр»  
Спеціальність 134 «Авіаційна та ракетно-космічна техніка»  
Освітньо-професійна програма «Обладнання повітряних суден»

## ЗАТВЕРДЖУЮ

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« \_\_\_ » \_\_\_\_\_ 2022 рік

## ЗАВДАННЯ

на виконання дипломної роботи студента

ВАН ЦЗУЯН

1. Тема роботи: «Аванпроект дальньоньомаргістрального пасажирського літака місткістю 240 пасажирів», затверджена наказом ректора №489/ст від 10 травня 2022 року.
2. Термін виконання проекту: з 23 травня 2022 р. по 19 червня 2022 р.
3. Вихідні дані до роботи: максимальна кількість пасажирів 240, крейсерська швидкість 841 км/год, дальність польоту 11000 км, крейсерська висота польоту 12,5 км.
4. Зміст пояснювальної записки: вступ, основна частина, що включає аналіз літаків-прототипів і короткий опис проєктованого літака, обґрунтування вихідних даних для розрахунку, розрахунок основних льотно-технічних та геометричних параметрів літака, компонування пасажирської кабіни, розрахунок центрування літака, спеціальна частина, яка містить моделювання несучої конструкції крила.
5. Перелік обов'язкового графічного матеріалу: загальний вигляд літака (A1×1), компонувальне креслення фюзеляжу (A1×1), моделювання силових елементів крила під навантаженням (A3×2).
6. Календарний план-графік:

№ пор	Завдання	Термін виконання	Відмітка про виконання
1	Вибір вихідних даних, аналіз льотно-технічних характеристик літаків-прототипів.	23.05.2022 – 26.05.2022	
2	Вибір та розрахунок параметрів проєктованого літака.	27.05.2022 – 30.05.2022	
3	Виконання компоунування літака та розрахунок його центрування.	31.05.2022 – 03.06.2022	
4	Розробка креслень по основній частині дипломної роботи.	04.06.2022 – 06.06.2022	
5	Моделювання конструкції крила та розробка креслень по спеціальній частині.	07.06.2022 – 11.06.2022	
6	Оформлення пояснювальної записки та графічної частини роботи.	12.06.2022 – 13.06.2022	
7	Захист дипломної роботи.	14.06.2022 – 19.06.2022	

7. Дата видачі завдання: 23 травня 2022 рік.

Керівник дипломної роботи \_\_\_\_\_ Володимир  
КРАСНОПОЛЬСЬКИЙ

Завдання прийняв до виконання \_\_\_\_\_ Ван Цзуйн

# NATIONAL AVIATION UNIVERSITY

Aerospace Faculty  
Department of Aircraft Design  
Academic degree "Bachelor"  
Specialty 134 "Aviation and aerospace technologies"  
Educational professional program "Aircraft equipment"

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Head of the Department Dr.Sc.,  
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«\_\_\_» \_\_\_\_\_ 2022

## TASK

for the bachelor degree thesis

WANG ZUYANG

1. Topic: "Preliminary design of the long-range passenger aircraft with 240 passengers capacity" confirmed by Rector's order №489/CT 10.05.2022.
2. Thesis term: since 23.05.2022 till 19.06.2022.
3. Initial data: cruise speed 841 km/h, flight range 11000 km, operating altitude 12,5 km, 240 passengers.
4. Content (list of topics to be developed): introduction, main part: analysis of prototypes and brief description of designing aircraft, selection of initial data, wing geometry calculation and aircraft layout, landing gear design, engine selection, center of gravity calculation, special part: static stress-strain analysis of the wing structure.
5. Required material: general view of the airplane (A1×1), layout of the airplane (A1×1), modelling of the wing structure (A3×2).
6. Thesis schedule:

#	Task	Time limits	Done
1	Selection of initial data, analysis of flight technical characteristics of prototypes aircrafts.	23.05.2022 – 26.05.2022	
2	Selection and calculation of the aircraft designed parameters.	27.05.2022 – 30.05.2022	
3	Performing of aircraft layout and centering calculation.	31.05.2022 – 03.06.2022	
4	Development of drawings on the thesis main part.	04.06.2022 – 06.06.2022	
5	Modelling of the wing structure and making drawings on a special part.	07.06.2022 – 11.06.2022	
6	Formatting an explanatory note and a graphic part of the diploma work.	12.06.2022 – 13.06.2022	
7	Defense of the diploma work.	14.06.2022 – 19.06.2022	

7. Date: 23.05.2022.

Supervisor \_\_\_\_\_

Volodymyr  
KRASNOPOLSKII

Student \_\_\_\_\_

Wang ZUYANG

## РЕФЕРАТ

Дипломна робота «Аванпроект дальньоньомагістрального пасажирського літака місткістю 240 пасажирів» містить:

50 сторінок, 16 рисунків, 7 таблиць, 15 літературних посилань

Авіалайнер цивільної авіації, розроблений у цій роботі, є пасажирським літаком, здатним перевозити 240 пасажирів та їх багаж для виконання польоту на велику відстань (11 000 км). За відповідними формулами та вибраними вихідними даними габаритні розміри літака, такі як довжина фюзеляжу, діаметр фюзеляжу, висота кабіни тощо, використовуються для завершення планування кухні та санвузла та розташування сидінь у кабіни. Після цього з визначенням масової частки кожного компонента та максимальної злітної маси літака завершується розрахунок ваги кожного компонента, а також розрахунок відповідного положення центру ваги та вагового моменту кожного компонента.

Потім, відповідно до розміру крила літака, в САТІА встановлюється тривимірна цифрова модель крила, а матеріал, що використовується в крилі літака, який зазвичай використовується, використовується як матеріал, що використовується в крилі в цієї роботи, а потім модуль аналізу, включений до програмного забезпечення САТІА, використовується для розгляду розподілу напружень крила в ідеальних умовах, щоб переконатися, що напруга на крилі знаходиться в межах межі текучості вибраного матеріалу.

**Пасажирський літак, аванпроект літака, центрування літака, компанування пасажирської кабіни, розрахунок на міцність, аналіз напружено деформованого стану**

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## ABSTRACT

Explanatory note to the diploma work "Preliminary design of the long-range passenger plane with 240 passenger capacity" contains:

50 pages, 16 figures, 7 tables, 15 references

The civil aviation airliner designed in this article is a passenger aircraft capable of carrying 240 passengers and their luggage to complete medium-distance flight (11,000km). According to the relevant formulas and the selected initial data, the overall dimensions of the aircraft, such as fuselage length, fuselage diameter, cabin height, etc., are used to complete the layout design of the kitchen and bathroom and the arrangement of seats in the cabin. After that, with the basement of the mass fraction of each component and the maximum take-off weight of the aircraft, the calculation of the weight of each component is completed, as well as the corresponding center of gravity position calculation, and the weight moment of each component is calculated.

Then, according to the size of the aircraft wing, a three-dimensional digital model of the wing is established in CATIA, and the material used in the commonly used aircraft wing is used as the material used in the wing in this article, and then the analysis module included in the CATIA software is used to consider the stress distribution of the wing under ideal conditions to ensure that the stress on the wing is within the yield strength range of the selected material.

**Passenger aircraft, preliminary design, center of gravity calculation, passenger cabin layout, strength calculation, stress-strain analysis**

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## **LIST OF ABBREVIATIONS**

RPK	Revenue passenger-kilometres
LG	Landing gear
APU	Auxiliary power unit
LP	Low pressure
HP	High pressure
IATA	International aviation transport association
ICAO	International civil aviation organization
FAR	Federal aviation regulation
CS	Certification specification
CCAR	Chinese civil aviation regulation
FC	Flexible conveyor
CM	The center of the mass

## Introduction

With the economic development today, we have realized that more and more people are able to choose a faster way for their travel, and flying is the fastest way. In this context, passenger traffic is increasing significantly. Especially in airlines, the demand for passenger transportation has greatly increased. In this regard, in order to be able to increase the company's profits, more mid-range passenger aircraft are needed. Only in this way can we achieve stable profitability with higher reliability, higher stability and medium-range distance advantages in the highly competitive global market. Therefore, civil aviation needs new aircraft that meet the requirements of the International Air Transport Organization, especially:

- Flight safety;
- Increase comfortable operation;
- Reduce the emission of harmful gases;
- Able to create benefits more likely;

The aircraft that is put into service must also meet the following requirements:

- Comfortable cabin that meets the highest requirements;
- Take off and land on unequipped, unpaved runways;
- Operate in a wide temperature range;
- Reliability and ease of operation.

The purpose of this Diploma work is to design an aircraft for transporting 150 passengers and luggage at mid ranges routes.

## **PART 1. PRELIMINARY DESIGN OF THE AIRCRAFT**

### **1.1. Choices of the projected data**

The selection of parameters for optimizing aircraft design is a multi-faceted optimization task, and during this period, the take-off weight and/or cost of the aircraft should be reduced as much as possible. First of all, the most basic is the choice of flying mechanism type, because the choice of flying mechanism type is related to flight technology, weight, geometric parameters, aerodynamics and economic characteristics. In the first stage, the use of approximate aerodynamics, statistical correlation, and statistical methods are used to determine the "aircraft shape". In the second stage, full aerodynamic calculations are used to determine the total weight of the aircraft based on our initial data, physical theory, aerodynamic principles and related mathematical formulas.

The prototype aircraft A330 is used to design the aircraft and provide relevant data as a reference. The aircraft can accommodate 240-340 passengers. The aircraft like Boeing 727-100, Boeing 727-200, Boeing 727-200Adv will complete with the designed aircraft in the category market. The detailed statistics of the prototype are shown in Table 1.1.

Table 1.1 – Operational-technical data of prototypes

INITIAL DATA AND SELECTED PARAMETERS			
Passenger number	240	Fuel-to-weight ratio	0.4510
Flight crew number	2	Aspect ratio	10.06
Flight attendant or	8	Taper ratio	3.00
Mass of operational	3601.05kg	Mean thickness ratio	0.110
Payload mass	26400kg	Wing sweepback at	31°
Cruising speed	870km/h	High-lift device	0.930
Cruising mach	0.8162	Relative area of wing	0.000
Design altitude	12.5km	Wing airfoil type	Supercritical
Flight range with	10800km	Winglets	No
Runway length for	2.195km	spoilers	Yes
Engine number	2	Fuselage diameter	5.6m
Thrust-to-weight	2.6	Fineness ratio of the	9.00
Pressure ratio	34.8	Horizontal tail sweep	35°
Accepted bypass	5	Vertical tail sweep	45°
Optimal bypass	5		

The design scheme and specific layout of the aircraft are determined by the relative position, shape and quantity of each unit of the aircraft. The aerodynamic characteristics of the aircraft and the operational characteristics during flight depend on the aerodynamic shape, external layout and aerodynamic design of the aircraft. Fortunately, with the development of science and technology, the advanced avionics



system of aircraft can improve the safety and stability of the aircraft during flight. In addition to this, the economic efficiency of the aircraft can also be greatly improved.

## **1.2. Brief description of the aircraft**

The aircraft is a low-wing monoplane fixed-wing aircraft with two turbojets under the wings, one on each side. Also equipped with three-point landing gear, there is a single front landing gear and four main landing gear connected to the middle of the fuselage.

**Fuselage.** The fuselage is a beam-column-based structure entirely constructed of metal. This type of structure is characterized by the presence of a relatively thick skin that is primarily loaded by beams and frames.

According to the reasonable shape of the fuselage and the advantages that the components can be deformed and elongated under load, as well as the characteristics of reducing resistance as much as possible and having a relatively high load threshold.

Under the floor of the sealed part of the fuselage, there are the following sections: chassis nose landing gear (leakage), front cargo compartment, rear cargo compartment, technical compartment. Front and rear cargo compartments are sealed, each compartment has a hatch on the right side and is equipped with a container locking system

**Wing.** As the main aerodynamic surface of the aircraft, the wing is the main aerodynamic load bearing component. The component has a large load, and the low structure height brings many difficulties to the structure layout, and also puts forward higher requirements.

The aerodynamic design of a wing can be broken down into several independent design parts:

- Selection of basic parameters: area, span, taper ratio and sweep angle.
- Airfoil section distribution and twist angle.
- Conceive high lift devices and flight control surfaces.

**Tail unit.** The empennage and the wing also belong to the airfoil structure. Its structural form type is basically the same as that of the wing, and the principle of structural layout selection is generally the same. Here are some design features of the tail that are different from the wing.

The rear wing has many layout styles. For example, the vertical tail and the flat tail are respectively connected to the fuselage, and the T-shaped tail and vertical tail support the layout at the end of the flat tail. Due to the different layout forms of the tail, its load states are also different, which should be considered separately. Under normal circumstances, the tail is far from the center of gravity of the aircraft, the internal volume is relatively small, and the load is small. The main requirements of the structural layout are determined by the strength and stiffness.

**Crew cabin.** The cockpit of a transport passenger aircraft is generally set at the head of the fuselage to obtain a good external view. The size and shape of the fuselage head often depends on the number of people in the cockpit, the vision requirements, the overall layout and the tonnage of the aircraft.

The size and layout of the cockpit of a passenger aircraft mainly depends on the number of flight crew members. The classic layout of the cockpit is shown in the figure below.

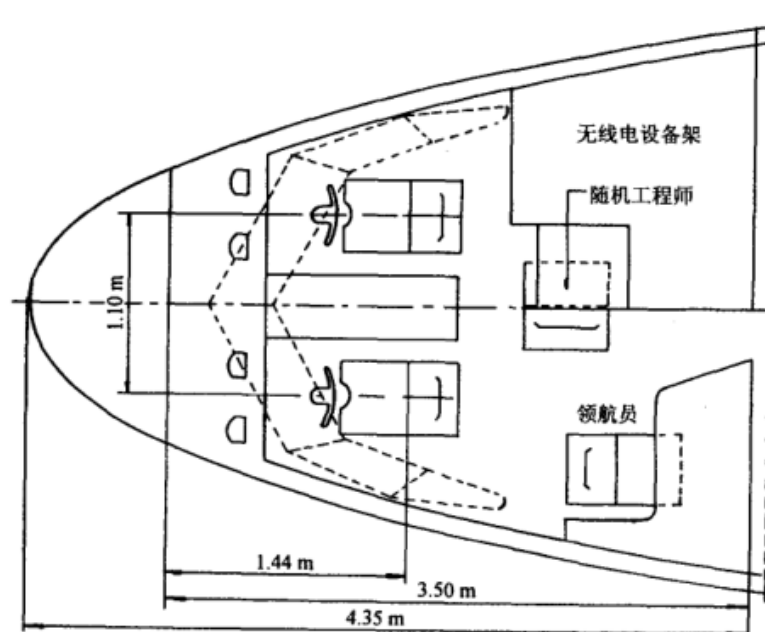


Fig1.1 The classical layout of the crew cabin

**Passenger furnishing.** The main factor considered in the cabin layout of civil aircraft is comfort, and the comfort of the cabin depends on the following factors: the design and arrangement of the seats, especially the adjustability and leg room; the layout and decoration of the cabin. Aesthetics; basic activity space for passengers in the cabin; adjustment of conditions such as moderate air pressure and temperature in the cabin; the size of cabin noise; the impact of aircraft acceleration on passengers; the impact of fuselage attitude on the interior when climbing and descending; endurance time; toilets , the convenience of lounges, kitchens, etc.; service quality.

**Control system.**The aircraft flight control system is used to transmit the pilot's control instructions, so that each control surface of the aircraft deflects according to the rules of the instructions, and generates aerodynamic control force and torque to achieve stable control of various flight attitudes. Therefore, it plays a great role in the flight safety and flight performance of the aircraft.

The control system of the early aircraft directly operated the rudder surface with the help of steel cables or pull rods. The pilot directly felt the change of the aerodynamic force on the rudder surface through the rod force and the tail of the rod, so as to feel the state of the aircraft and control the movement of the aircraft. With the increase of flight speed and the increase of the size and weight of the aircraft, it is difficult to control the aircraft by manpower alone. Therefore, hydraulic boosters that use hydraulic energy to overcome the load to drive the rudder surface appear. This technology was first applied to high-speed aircraft and heavy-duty aircraft, and only a small part of the load will be transferred to the control stick, allowing the pilot to feel more realistically.

**Spoilers.** Spoilers are panels mounted on the upper surface of the wing that, when extended, both increase drag and decrease lift by disrupting the airflow over the wing. Dependent upon the aircraft type, spoilers can serve as many as three distinct primary functions:

- Ground spoilers
- Roll spoilers

- (Flight) spoilers or Speedbrakes

Some aircraft such as the AIRBUS A-320 and the EMBRAER ERJ 190-100 have all three spoiler functions whereas the BA146 only incorporates the ground spoiler function. Certain aircraft designs also utilize the spoiler panels for secondary functions such as turbulence damping.

**Landing gear.** The landing gear is the principal support of the airplane when parked, taxiing, taking off, or landing. The most common type of landing gear consists of wheels, but airplanes can also be equipped with floats for water operations or skis for landing on snow.

The wheeled landing gear on small aircraft consists of three wheels: two main wheels (one located on each side of the fuselage) and a third wheel positioned either at the front or rear of the airplane.

Landing gear with a rear mounted wheel is called conventional landing gear. Airplanes with conventional landing gear are sometimes referred to as tailwheel airplanes. The two main wheels are attached to the airframe ahead of its centre of gravity (CG) and support most of the weight of the aircraft. The tailwheel is located at the very back of the fuselage and provides a third point of support. This arrangement allows adequate ground clearance for a larger nose-mounted propeller and is more desirable for operations on unimproved fields. It is therefore popular with small, general aviation aircraft such as the PIPER L-18C and the C170. With the CG located behind the main landing gear (MLG), directional control is more difficult while on the ground. For example, if the pilot allows the aircraft to swerve while rolling on the ground at a low speed, they may not have sufficient rudder control and the CG will attempt to get ahead of the main gear, which may cause the airplane to ground loop. Touching down with the tailwheel may, depending on the speed, produce enough lift (due to the increased Angle of Attack (AOA)) and cause the aircraft to become airborne again. Diminished forward visibility when the tailwheel is on or near the ground is another disadvantage of tailwheel landing gear airplanes. Specific training is required to operate tailwheel airplanes.

When the third wheel is located on the nose, it is called a nosewheel, and the design is referred to as a tricycle gear. It has the following advantages compared to the conventional type:

Allows more forceful application of the brakes during landings at high speeds without causing the aircraft to nose over.

Tends to prevent ground looping (swerving) by providing more directional stability during ground operation since the aircraft's CG is forward of the main wheels. This keeps the airplane moving forward in a straight line rather than ground looping.

Provides better forward visibility for the pilot during takeoff, landing, and taxiing.

A steerable nosewheel or tailwheel permits the airplane to be controlled throughout all operations while on the ground. Most aircraft are steered by moving the rudder pedals, whether nosewheel or tailwheel. Airplane brakes are located on the main wheels and are applied by either a hand control or by foot pedals (toe or heel). Foot pedals operate independently and allow for differential braking, i.e. applying different force to the left and right main landing gear assemblies. During ground operations, differential braking can supplement nosewheel/tailwheel steering.

Landing gear can also be classified as either fixed or retractable. Fixed landing gear always remains extended and has the advantage of simplicity combined with low maintenance. Retractable landing gear is designed to streamline the airplane (reduce the drag) by allowing the landing gear to be Stowed inside the structure during cruising flight. Fixed landing gear is common with slow (e.g. general aviation) aircraft and most commercial aircraft use retractable landing gear.

Heavier aircraft require more complex landing gear. These consist of multiple wheels and sometimes the MLG is made of more than two assemblies. For example, the Airbus A340 Family is equipped with a MLG comprising three parts (one under each wing and the third under the fuselage) and the AIRBUS A-380-800 and the Boeing B747 Series have four (one under each wing and two under the fuselage). Some

large cargo aircraft, e.g. the ANTONOV An-124 Ruslan and ANTONOV An-225 Mriya also have nose landing gears comprising two assemblies (in addition to the complex MLG design).

Retractable landing gear is normally powered by the hydraulic system. In the case of failure, an emergency extension system is available. This may be a manually operated crank or pump, or a mechanical free-fall mechanism. Airflow is sometimes used to get the gear into the locked position.

Landing with the gear in the "up" position or with an unlocked gear can lead to loss of directional control on the ground, a Runway Excursion, extensive structural damage or Fire, Smoke & Fumes.

### 1.3. Main parts of the aircraft calculations

We must compute the relative positions of the aircraft's components and various sorts of loads (passengers, luggage, food, fuel, cargo, etc.) when creating the layout of the aircraft, and compare the calculation results and various factors.

Finally, as a guide, select the parameters that best satisfy the design criteria.

#### 1.3.1. Wing geometry calculation

Geometrical characteristics of the wing are determined from the take of weight  $m_0$  and specific wing load  $P_0$ .

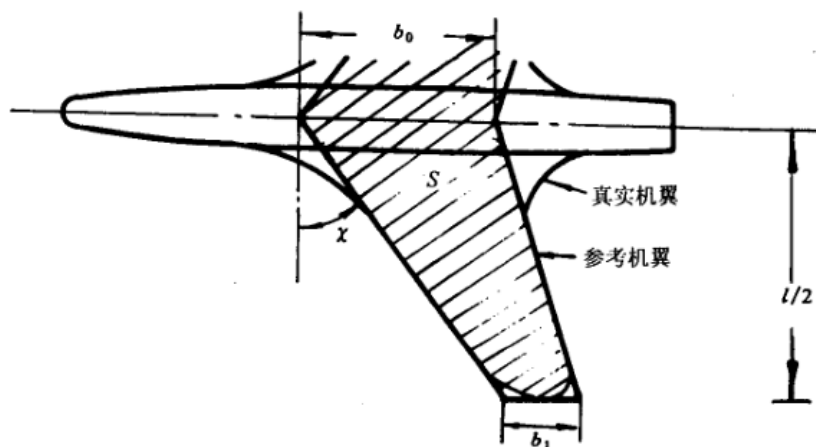


Fig 1.2 wing Geometric parameters

Wing area with extensions is:

$$A_w = \frac{m_0 \cdot g}{p_0} = 334m^2$$

Wing span is:

$$l = \sqrt{A_w \cdot \lambda_w} = 57.97m$$

Root chord and Tip chord is:

$$A_w = (C_{root} + C_{tip}) \cdot \text{span}$$
$$TR = \frac{C_{root}}{C_{tip}}$$
$$C_{root} = 4.3m \quad C_{tip} = 1.44m$$

Maximum wing width is determined in the forehead i-section and by its span it is equal:

$$c_i = c_w \cdot b_i = 0.11 \cdot 1.42 = 0.156m$$

We establish the number of longerons and their position, as well as the locations of wing portioning, while choosing a power scheme for the wing.

We employ xenon double – or triple – longeron wing on modern aircraft; longeron wing is widespread in light sport, sanitary, and personal aircrafts. There are three longerons on our plane.

This work calculate the mean aerodynamic chord using a geometrical method (figure 2.1). The average aerodynamic chord is:

$$b_{MAC} = 3.107m$$

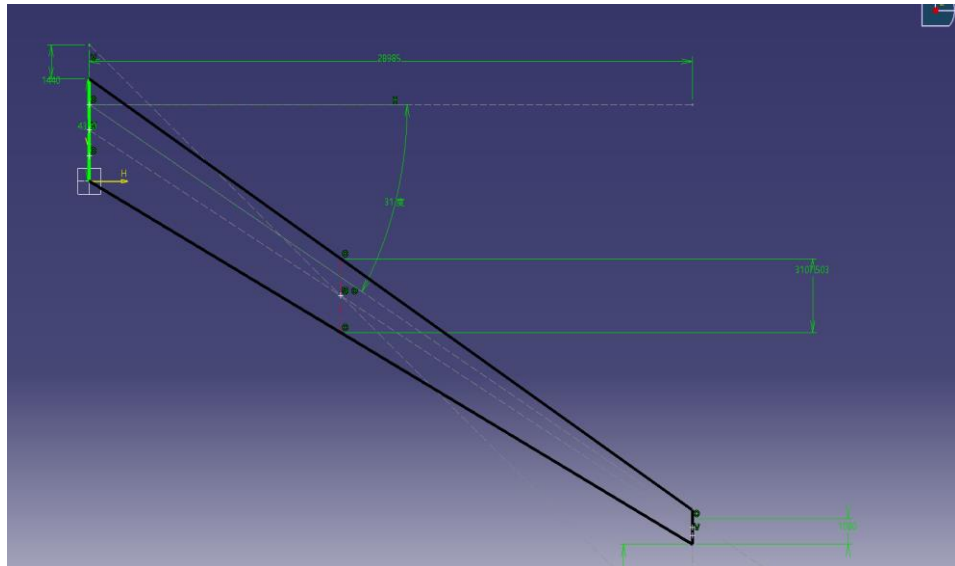


Figure 1.3 Determination of mean aerodynamic chord

After determination of the geometrical characteristics of the wing we come to the estimation of the ailerons geometrics and high-lift devices.

Ailerons geometrical parameters are determined in next consequence:

Ailerons span:

$$l_a = 0.3 \cdot \frac{57.75}{2} = 8.7m$$

Aileron area:

$$S_a = 10.855m^2$$

Width of ailerons:

$$b = 0.384 m$$



It is unnecessary and inconvenient to increase  $l_{ail}$  and bail over prescribed levels. The growth of the ailerons coefficient declines as  $l_{ail}$  exceeds a specific value, and the high-lift devices span decreases. The breadth of the xenon reduces as the bail is increased.

There is a trend in third-generation aeroplanes to reduce relative wing span and ailerons area. As a result,  $l_{ail} = 0.122$ . In this situation, spoilers and ailerons are used to control the airplane's transversal movement. As a result, the span and area of high-lift devices may be expanded, improving the aircraft's takeoff and landing characteristics.

Aerodynamic compensation of the aileron.

Axial  $S_{axinail} \leq (0.25 \dots 0.28)$

Inner axial compensation  $S_{inaxinail} = (0.3 \dots 0.31) S_{ail}$ ;

Area of ailerons trim tab.

Range of aileron deflection

Upward  $\delta'_{ail} \geq 20^\circ$ ;

Downward  $\delta''_{ail} \geq 10^\circ$ .

The purpose of determining the geometrical characteristics of wing high-lift devices is to provide take-off and landing coefficients of wing lifting force, which were assumed in earlier calculations with the chosen rate of high-lift devices and the type of airfoil profile.

Before doing the following calculations, select the kind of airfoil from the airfoil catalogue, specify the lift coefficient, and calculate the necessary increase for this coefficient for the high-lift devices outlet using the formula:

$$\Delta C_{y_{max}} = \left( \frac{C_{y_{maxl}}}{C_{y_{maxbw}}} \right).$$

Where  $C_{y_{maxl}}$  is necessary coefficient of the lifting force in the landing configuration of the wing by the aircraft landing insuring (it is determined during the choice is the aircraft parameters).

In the modern design the rate of the relative chords of wing high-lift devices is:

$b_f = 0.3 \dots 0.4$  – for three slotted flaps and Faylers flaps;

$b_s = 0.1..0.15$  – slats.

Because the effectiveness of high-lift devices ( $C_{y_{maxl}}^*$ ) increases proportionally to the wing span served by high-lift devices, we need to obtain the largest span of high-lift devices ( $l_{hld} = l_w - D_f - 2l_{ail} - l_n$ ) due to the use of a flight spoiler and the smallest engine and landing gear nacelles possible.

This work must use statistics and expertise from domestic and international aircraft building to choose structurally-power schemes, hinge-fitting schemes, and kinematics of high-lift devices. It's worth noting that the bulk of existing structures use longeron structurally-power techniques to implement high-lift devices.

### **1.3.2. Fuselage layout**

This work must start with the aerodynamic considerations when deciding on the form and size of the fuselage cross section (streamlining and cross section).

Wave resistance has little effect on subsonic passenger and cargo aircraft ( $V$  less than 800 km/h). As a result, we must select from the list of conditions friction resistance  $C_{xf}$  and profile resistance  $C_{xp}$ .

The value of wave resistance  $C_{xw}$  is affected by the shape of the fuselage nose part during transonic and subsonic flights. The use of a round form for the fuselage nose part reduces wave resistance greatly.

When selecting a cross section form, we must consider the strength and layout requirements as well as the aerodynamic parameters.

The most practical fuselage cross section shape for achieving lowest weight is a circular cross section. We have the smallest fuselage skin width in this scenario. We can utilise a combination of two or more vertical or horizontal series of circles as a partial instance. For cargo aircrafts the aerodynamics is not so important in the fuselage shape choice, and the cross section shape is may be close to rectangular one.

To geometrical parameters we concern: fuselage diameter  $D_f$ ; fuselage length  $l_f$ ; fuselage aspect ratio  $\lambda_f$ ; fuselage nose part aspect ratio  $\lambda_{np}$ ; tail unit aspect ratio  $\lambda_{TU}$ . Fuselage length is determined considering the aircraft scheme, layout and airplane

center-of-gravity position peculiarities, and the conditions of landing angle of attack  $\alpha_{land}$  ensuring.

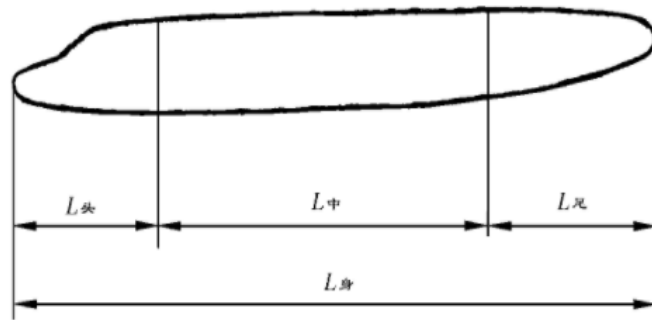


Fig 1.4 Split the three-section structure of the fuselage(the length of the nose part, central part and rear part of the fuselage)

Fuselage length is equal:

$$l_f = FR \cdot D_f = 50.4m$$

Fuselage forward part is equal:

$$l_{aft} = l_f * 0.12 = 6.06m$$

Fuselage nose part aspect ratio is equal:

$$l_{nose} = l_f * 0.14 = 7.23m$$

This work strive to approach minimum mid-section Sms from one side and layout demands from the other while determining fuselage length.

The size of the passenger cabin determines the fuselage mid-section for passenger aeroplanes. The height of the passenger cabin is one of the most important factors in determining the mid-section of a passenger airliner.

For economic and business cabin with the scheme of allocation of seats in the one row (2 + 2+2)

For three seats of one block distribution we may take the width as: (3\*3)

economic class seat width  $b_{3ec}=1455.....1650mm$  ;

business class seat width  $b_{3bu}=1500.....1770mm$ ;

The distance from the outside of the seat handle to the inner wall of the fuselage  $\delta_1=40.....50mm$ ;

The distance between inner and outer walls of the fuselage  $\delta_{wall}=80.....120mm$  ;

For aisle width we may take as:

$b_{ais-ec}=400.....510mm$ ;

$b_{asi-bu}=500.....600mm$ ;

The appropriate width of the economic cabin is equal:

$$b_{eccabin} = 6170mm$$

For business cabin with the scheme of allocation of seats in the one row (3 + 3)

The appropriate width of the business cabin is equal:

$$b_{bccabin} = 5020mm$$

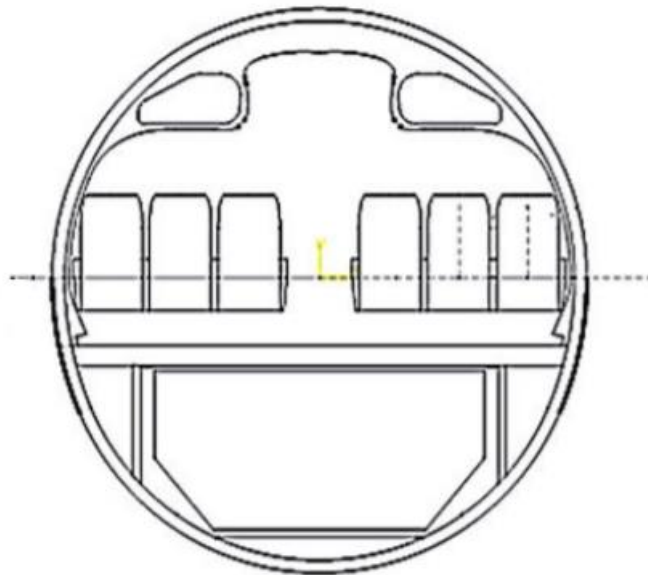


Fig 1.5 Cross-sectional display of the fuselage cabin

The circular cross-sectional design is the strongest and lightest in terms of design. Theoretically, we'll go with a circular cross-sectional shape. However, in terms of passenger and cargo placement, this design is not the best. In most circumstances, a combination of two intersecting circles, or the fuselage's ellipse, is the most appropriate method. The circular design is not ideal for production since the upper and lower panels will bend owing to increased pressure, necessitating the inclusion of bilge beams and other structural modifications.

The usual bulkhead step in the fuselage construction ranges from 360 to 500mm, depending on the fuselage type and passenger saloon class.

Consideration of the design We don't utilise this shape for diameters smaller than 2800mm and instead use the intersecting circles cross section. The floor of the passenger saloon is done in this case in the plane of are shutting.

The windows are arranged in a light-filled row. The window can be round or rectangular with rounded corners, having a dimension of 300...400mm. The window step is 500...510mm and matches to the bulkhead step.

After that, we'll figure out how long the passenger cabin is. According to the cruise time, I chose the seat allocation of economy class (3+3+3) and business class (2+2+2), therefore economic class can be configured with 210 passenger seats (22 rows total)

and business class can be configured with 30 passenger seats (5 rows total). From the following parameters, we can choose the appropriate seat pitch value.

seat pitch (shown at table 1.2).

Table 1.2 – Seat pitch selection reference table

type of class	less than 3hours	more than 3hours
first	1020	1080
business	960	960
economic	810	870

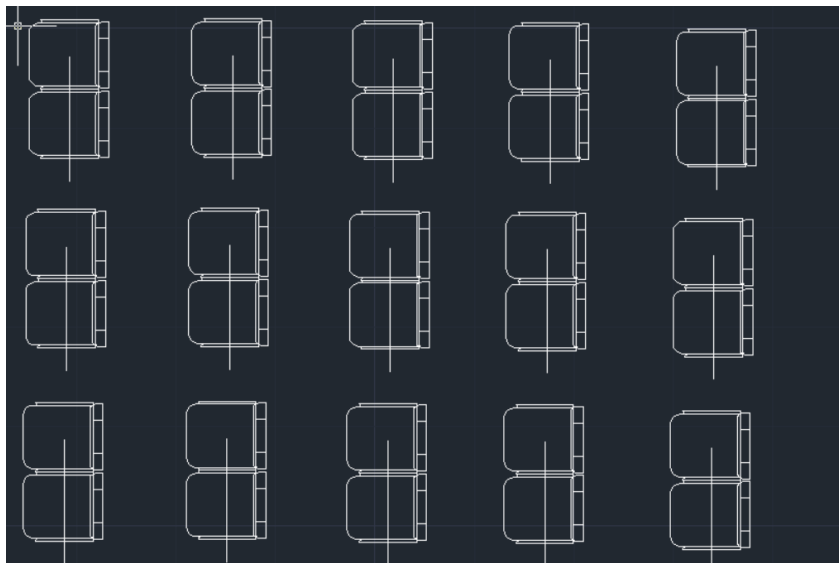


Fig 1.6 layout of the business cabin



Fig 1.7 layout of the economy cabin

The length of economic passenger cabin is equal:



$$L_{eccabin} = L_1 + (n_{rows} - 1) \cdot L_{seatpitch} + L_2 = 15.7m$$

The length of business passenger cabin is equal:

$$L_{bccabin} = L_1 + (n_{rows} - 1) \cdot L_{seatpitch} + L_2 = 10.09m$$

### 1.3.3. Luggage compartment

Given the fact that the unit of load on floor  $K = 400 \dots 600 \text{ kg/m}^2$

The area of cargo compartment is defined:

$$S_{cargo} = \frac{M_{bag}}{0.4K} + \frac{M_{cargo\&mail}}{0.6K} = 35m^2$$

Cargo compartment volume is equal:

$$V_{cargo} = v \cdot n_{pass} = 48m^3$$

Luggage compartment design similar to the prototype

### 1.3.4. Galleys and buffets

If the plane has a mixed configuration, international rules state that two dishes must be prepared. If the trip is less than 3 hours long, meals will not be served to passengers; instead, cupboards with water and tea will be provided. Buffets and bathrooms could not be provided for flights with a duration of less than one hour. Kitchen cupboards must be located near the door, preferably between the cockpit and the passenger or cargo doors. Refreshment and food cannot be kept near the toilets or in close proximity to the wardrobe.

Volume of buffets(galleys) is equal:

$$V_{galley} = 24m^3$$

Height of cabin is equal:

$$h = 0.296 + 0.383D_f = 2.44m$$

Area of buffets(galleys) is equal:

$$S_{galley} = \frac{V_{galley}}{h} = 9.84m^2$$

Breakfast, lunch, and supper – 0,8 kg each passenger; tea and water – 0,4 kg; if food is arranged once, it is assigned a fixed number 1 weighing 0,62 kg. Every 3.5–4 hour flight, food travellers arrive.

The design of the buffet is identical to that of the prototype.

### 1.3.5 Lavatories

The number of bathroom facilities is decided by the number of passengers and flight duration: one toilet for 40 passengers at  $t > 4$  hours, two toilets for 50 passengers at  $t = 2... 4$  hours, and two toilets for 60 passengers at  $t 2$  hours.

The number of lavatories I choose according to the original airplane and it is equal:

$$n_{lav} = 3$$

Area of lavatory:

$$S_{lav} = 1.5m^2$$

Width of lavatory: 1m.

Toilets design similar to the prototype.

### 1.3.6. Layout and calculation of basic parameters of tail unit

The placement of the tail unit is one of the most essential aspects of the aerodynamic layout. The aircraft's centre of gravity should be situated in front of the aircraft focus to ensure longitudinal stability during overloading, and the distance between these places, which is connected to the mean value of the wing aerodynamic chord, affects the rate of longitudinal stability.

$$m_x^{Cy} = \bar{x}_T - \bar{x}_F < 0$$

The moment coefficient is  $m_{Cy}$ , while the centre of gravity and focus coordinates are  $x_T$ .  $x_F$ . If  $m_{Cy}=0$ , the plane has neutral longitudinal static stability; if  $m_{Cy}>0$ , the plane has statically instable longitudinal stability. The centre of the combination wing – fuselage during the installation of the tail unit is pushed back in



the usual aircraft scheme (tail unit is behind the wing).

Horizontal  $A_{htu}$  and vertical  $A_{vtu}$  are the static ranges of static moment coefficients, as shown in the table, with typical arm  $H_{tu}$  and  $V_{tu}$  correlations. The first way to determining geometrical parameters may be found in the table.

The geometrical parameters of the tail unit are determined.

Area of vertical tail unit is equal:

$$S_{VTU} = \frac{l_w S_w}{L_{VTU}} A_{VTU} = 50.1 m^2$$

Area of horizontal tail unit is equal:

$$S_{HTU} = 66.8 m^2$$

Length of horizontal tail unit is equal:

$$\frac{L_{HTU}}{b_{MAC}} = 2.5 \dots 3.5;$$

$$L_{HTU} = 8.1795 m$$

### 1.3.7. Landing gear design

Only the part of landing gear parameters may be established at the primary stage of design, when the aeroplane center-of-gravity position is specified and there is no drawing of the aeroplane general view.

Main wheel axel offset is:

$$e = 0.2673 b_{MAC} = 0.625$$

When the back of the aeroplane is loaded first, the lift-off of the front gear during take-off is problematic, and when the back of the aeroplane is loaded first, the drop of the aeroplane on the tail is conceivable. The term "landing gear wheel base" derives from the phrase:

$$B = 0.4526 L_f = 21.45 m$$

$$B_m = 0.175 * 3.1 = 0.5425 m$$

$$B_n = B - B_m = 20.9125 m$$

The last equation means that the nose support carries 6...10% of aircraft weight.

Front wheel axial offset will be equal:



$$d_{ng} = B - e = 20.825m$$

Wheel track is:

$$T = 0.6072B = 13.02m$$

The value K should be more than 2H in order to prevent side nose-over, where H is the distance from the runway to the centre of gravity.

The landing gear wheels are chosen based on their size and run loading from the take-off weight; we also consider dynamic loading for the front support.

The runway surface, which should be utilised, determines the kind of pneumatics (balloon, half balloon, arched) and the pressure in it. We put brakes on the main wheel, as well as the front wheel on occasion.

The load on the wheel is calculated using the following formula:  $K_g = 1.5...2.0$  – dynamics coefficient.

Nose wheel load is equal:

$$P_{NLG} = \frac{(9.81ek_g m_0)}{Bz} = 49708.71635N$$

$$P_{NLG} = \frac{(9.81 \cdot e \cdot k_g \cdot m_0)}{(B \cdot z)} = \frac{(9.81 \cdot 1.46608 \cdot 1.75 \cdot 91295)}{(18.920 \cdot 2)} = 60724.0307N$$

Main wheel load is equal:

$$P_{NLG} = \frac{(9.81(B - e)m_0)}{Bnz} = 157742.3265N$$

### 1.3.8. Choice and description of power plant

GE CF6 (except -200F) /PW4000 / Trent 700 - a high bypass turbofan engine, in various modifications installed on passenger aircraft like A330,A310,A330 and so on.

Table 1.3 – Examples of application GE CF6-6 and its specifications

Model	Thrust	Bypass ratio	Dry weight
<b>CF6-6</b>	41,500 lbf 185 kN	5.76-5.92	3709 kg
<b>CF6-50</b>	51,500–54,000 lbf 229–240 kN	4.24-4.4	4102kg
<b>CF6-80A</b>	48,000–50,000 lbf 210–220 kN	4.59-4.66	4016kg

#### **1.4. Center of gravity calculation**

##### **1.4.1. Trim-sheet of the equipped wing**

A fully equipped wing's mass includes the structure's mass, the mass of the equipment installed in the wing, and the mass of the fuel. The main landing gear and front gear are included in the mass of a fully equipped wing, regardless of where they are installed (on the wing or the fuselage). Include the objects' names, as well as their barycentric coordinates and masses. The front nose point of the mean aerodynamic chord (MAC) of the surface XOY is projected to determine the origin for a given centroid position. The following formula determines the position of the wing's longitudinal centre of gravity.

$$X'_w = \frac{\sum m'_i x'_i}{\sum m'_i}$$

Table 1.4- Trim sheet of equipped wing

N	object name	Mass		C.G coordinates	Mass moment
		units	total mass		
1	wing (structure)	0.1262	25081.9976	1.39815	35068.39494
2	fuel system	0.0126	2504.2248	1.33601	3345.669375
3	Flight control system , 30%	0.0012	238.4976	1.8642	444.6072259
4	electrical equipment, 10%	0.00269	534.63212	0.3107	166.1101997
5	anti-ice system , 40%	0.00696	1383.28608	0.3107	429.7869851
6	hydraulic systems , 70%	0.00854	1697.30792	1.8642	3164.121424
7	power plant 2,3	0.04507	8957.57236	-2	- 17915.14472
8	power plant 1,4	0.04507	8957.57236	-2.5	-22393.9309
9	equipped wing without landing gear and fuel	0.24833	49355.09084	- 0.752606338	-37144.9542
10	nose landing gear	0.00603	1198.45044	-0.36043	- 431.9574921
11	main landing gear	0.02747	5459.60756	1.70885	9329.650379
12	fuel	0.3962	78743.9576	1.30494	102756.14
13	total	0.67803	134757.1064	4.484713662	111653.8329

#### 1.4.2. Trim-sheet of the equipped fuselage

The origin of the coordinates is picked in the horizontal axis projection of the fuselage's snout. The fuselage construction portion is specified for the axis X. Table 1.6 shows an example list of items for the AC, including which engines are installed beneath the wing.

The CG coordinates of the FEF are determined by formulas:

$$X_f = \frac{\sum m_i' X_i'}{\sum m_i'};$$

After we determined the C.G. of fully equipped wing and fuselage, we construct the moment equilibrium equation relatively to the fuselage nose:

$$m_f x_f + m_w (x_{MAC} + x_w') = m_0 (x_{MAC} + C)$$

From here we determined the wing MAC leading edge position relative to fuselage, means  $X_{MAC}$  value by formula:

$$X_{MAC} = \frac{m_f x_f + m_w \cdot x_w' - m_0 C}{m_0 - m_w},$$

where  $m_0$  – aircraft takeoff mass, kg;  $m_f$  – mass of fully equipped fuselage, kg;  $m_w$  – mass of fully equipped wing, kg;  $C$  – distance from MAC leading edge to the C.G. point, determined by the designer.

$C = (0,22...0,25) \mathbf{B}_{MAC}$  –low wing ;

**Table 1.5 – Trim sheet of equipped fuselage**

N	objects names	Mass		C. G coordinates	mass moment
		units	total mass		
1	fuselage	0.077	15440.732	25.2	389106.4
2	horizontal tail	0.009	1852.3313	8.1795	15151.14
3	vertical tail	0.009	1911.9557	8.1795	15638.84
4	radar	0.002	476.9952	0.5	238.4976
5	radio equipment	0.001	357.7464	1	357.7464
6	instrument panel	0.004	834.7416	2.5	2086.854
7	aero navigation equipment	0.003	715.4928	2	1430.985
8	Flight control system 70%	0.002	556.4944	25.2	14023.65
9	hydraulic system 30%	0.003	727.41768	35.28	25663.29
10	electrical equipment 90%	0.024	4811.6890	25.2	121254.5
11	not typical equipment	0.010	2007.3548	18	36132.38
12	lining and insulation	0.009	1927.8556	25.2	48581.96
13	anti ice system, 20%	0.003	691.64304	40.32	27887.04
14	airconditioning system, 40%	0.006	1383.2860	25.2	34858.80
15	Equipment for Container Loading (bagage compartment)	0.004	953.9904	12	11447.88
16	passenger seats (bussiness)	0.001	225	11.34	2551.5
17	passenger seats (economic class)	0.0070	1400	32	44800
18	seats of flight attendance	0.0003	60	12	720
19	seats of pilot	0.0001	24	4	96
20	Emergency equipment	0.0001	28	28	784
21	lavatory1, galley 1	0.005	1003.677	12	12044.1

**Continuation of the table 1.5**

N	objects names	Mass	C. G coordinate s	mass moment	
26	Passengers (bussiness)	0.011	2310	11.34	26195.4
27	on board meal	0.001	360	26	9360
28	baggage	0.024	4800	12	57600
29	cargo, mail	0.009	1800	12	21600
30	Flight atttnedance	0.001	360	12	4320

31	crew	0.000	154	4	616
32	Passengers (economy)	0.084	16800	32	537600
33	TOTAL	0.352	69960.69	23.890969 5	1671428.

According to the table 1.5:

$$X_{MAC} = \frac{mf \cdot xf + mw \cdot x'w - moC}{mo - mw} = 25.7416m$$

### 1.4.3. Calculation of center of gravity positioning variants

The list of mass objects for centre of gravity variant calculation given in table 1.7 and Center of gravity calculation options given in table 1.8, completes on the base of both previous tables.

Table 1.6 – Calculation of C.G. positioning variants

N	Name	mass	coordinate	mass moment
1	equipped wing (without fuel and landing gear)	49355.09084	24.99027224	1233397.156
2	Nose landing gear (extended)	1198.45044	5	5992.2522
3	main landing gear (extended)	5459.60756	25	136490.189

4	equipped fuselage (without payload)	43376.69348	23.37797765	1014059.371
5	passengers of business class	2310	11.34	26195.4
6	passengers of economy class	16800	32	537600
7	baggage	4800	12	57600
8	cargo	1800	12	21600
9	crew	154	4	616
10	nose landing gear (retracted)	1198.45044	26	31159.71144
11	main landing gear (retracted)	5459.60756	4	21838.43024
12	fuel/fuel reserve	5869.02844	25	146725.711
13	fuel	78743.9576	25	1968598.94

Table 1.7 – Airplane C.G. position variants

N	Name	Mass	Mass moment	Center of mass	C. G position
1	take off mass (L.G. extended)	209866.828	5148875.02	24.53401073	0.390933306
2	take off mass (L.G. retracted)	209866.828	5059390.72	24.10762463	0.3231339
3	landing weight (LG extended)	137780.928	3233274.22	23.46677621	0.2398167
4	ferry version	190025.856	4416395.32	23.24102306	0.2032231
5	parking version	105258.870	2536664.68	24.09929597	0.15

### Conclusion to part 1

According to the Diploma paper task, the following issues were addressed in section 1:

- an early design for a middle-range aircraft with a capacity of 2400 passengers;



- interior layout of a medium-range aircraft with 240 passengers; -calculation of the airplane's centre of gravity; -calculation of the key geometrical characteristics of the landing gear;

-wheel selection that meets criteria; -wheel brake selection that meets requirements; -nose landing gear design

- At low-wing aircraft, three engines are located in the back of the fuselage; - reasonable fuselage layout and easy service;

- rational layout and easy service;

- ergonomic optimization of communal and private space; - modern interior design;

- low noise

The low-wing plane has three engines at the back of the fuselage, which enhances the wing's aerodynamic qualities, lessens the influence of engine jets on the wing, and reduces cabin noise.

Both international and Chinese airworthiness criteria are met by the initial design.

## **PART 2 THE STATIC ANALYSIS OF WING**

### **2.1 Introduction**



After selecting the basic component structure of the aircraft and completing the calculation of its center of gravity, we need to perform force analysis on each component of the aircraft.

The early idea of static strength design mainly adopts the method of theoretical calculation, but the desired calculation result cannot be accurately obtained in the actual engineering calculation. The finite element calculation method is a very suitable method of approximate solution to solve problems in continuous domains. Through the finite element method we can solve many complex practical engineering problems.

In order to make the wing of the aircraft meet the basic requirements when it is stationary on the ground, the aircraft structure needs to be able to work normally under the predetermined gravity load, so it is necessary to check its structural strength. This paper uses the finite element analysis module of CATIA to analyze the static strength of the wing.

The finite element method is based on the idea of block and establishes the connection between the nodal displacement and the nodal force according to the variational principle. In practical physical problems, there are loads inside each block sub-unit, such as surface and body forces, which often need to be equivalent to the position of the node to make the node move, and the unique hand of the internal point of the unit is used. The induced displacement, which is regarded as the nodal displacement, is also called the interpolated displacement, and is characterized by the weighted form of the nodal displacement .

In this paper, the structure of the wing is simplified, and the purpose is to study the deformation of the curved plate of this type of airfoil under ideal conditions.

In this paper, the following aspects are mainly considered when modeling the finite element structure of the wing:

- (1) Modeling of the wing.
- (2) Simulation under load conditions.

## **2.2 Introduction to CATIA software**

CATIA originated from the aerospace industry and is the undisputed leader of the industry. With its precision, safety and reliability, it meets the needs of various

applications in the commercial, defense and aerospace fields. CATIA V5 software is a CAD/CAE/CAM integrated software, which provides a powerful and easy-to-use engineering analysis module—Analysis & Simulation. Using this module, you only need to define loads and constraints similar to practical engineering problems to quickly implement basic finite element analysis. Commonly used functions include finite element analysis of individual parts GPS (Generative Part Structural Analysis) and finite element analysis of assemblies GAS (Generative Assembly Structural Analysis). Its engineering analysis module can perform computational analysis on many problems such as electricity, structure, fluid, thermodynamics, electromagnetic fields, man-machine integration and collision. Therefore, it is often used in industrial fields such as the automotive industry, aerospace, construction, biomedicine, bridges, electronic products, heavy machinery, sports equipment, and MEMS .

When performing finite element analysis, the CATIA program provides easy-to-use, high-quality meshing of the model. The free mesh division function of the CATIA program is very powerful, and it can directly divide complex models, avoiding the trouble caused by the mismatch of meshes when the user divides each part separately and then assembles it. Adaptive meshing is that after a solid model with boundary conditions is generated, the user instructs the program to automatically generate a finite element mesh, analyze and estimate the discrete error of the mesh, and then redefine the mesh size, analyze, calculate, and estimate the mesh again. Discrete error of the lattice until the error falls below a user-defined value or reaches a user-defined number of solutions

### **2.3 The model of the wing structural**



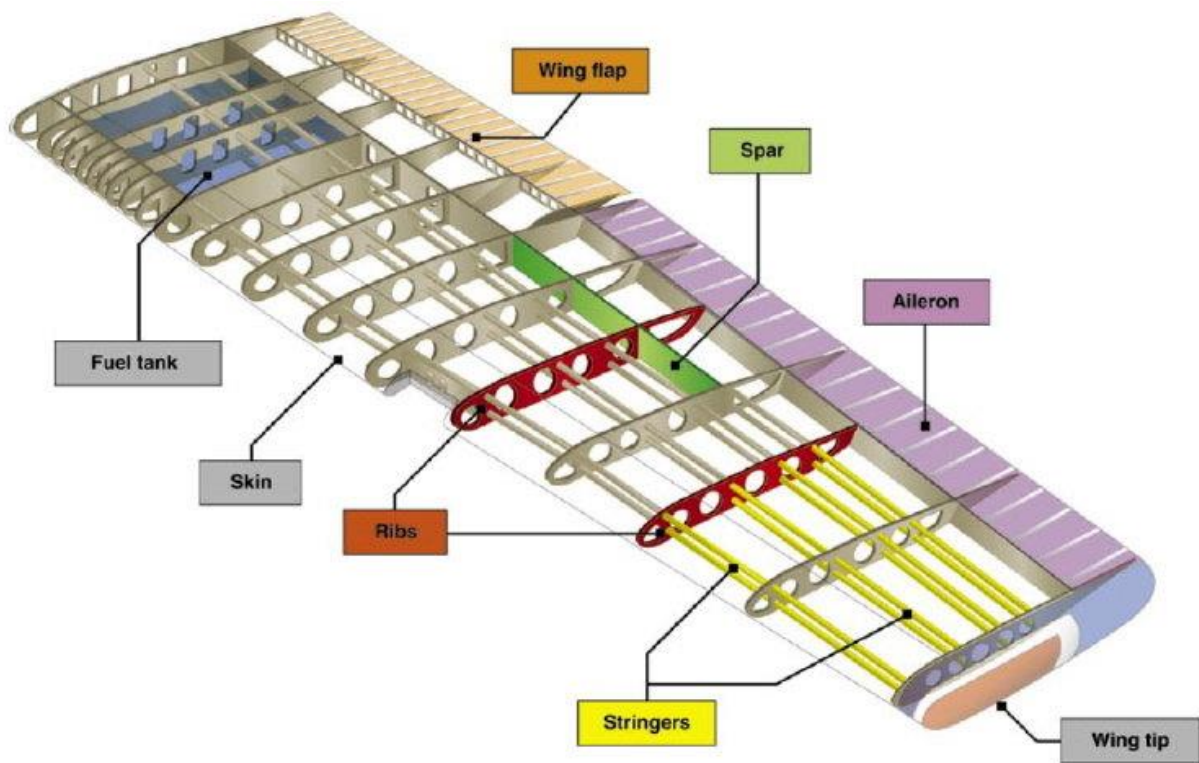


Fig 2.1 The structural of the wing

The function of every part of the wing is introduced below

par Cap (flange):

The top and lower flanges, which are connected to the spar webs, make up this section. The bending moment generated by the wing in flight is carried by the spar caps. For a positive load factor, the top spar cap will be loaded in compression and the lower spar cap in tension (wing bending upward). The spar caps also serve as a border for attaching the wing skin and provide support against buckling. The main spar is used to attach concentrated load locations such as engine mounts and landing gear.

Spar web:

The spar web is made up of the material that connects the spar caps and keeps them at a consistent distance apart. During flight, the spar caps can function in pure tension and compression (bending). The vertical shear loads (lift) that result from the wing's aerodynamic loading are carried by the spar web. The wing spar is made up of the webs and caps of the spars.

Wing Ribs:

The ribs are positioned equidistant from one another (to the extent possible) and aid in maintaining the wing's aerodynamic profile. The ribs support the skins and stiffeners against buckling and are part of the border upon which the skins are fastened. Ribs are also an excellent structure for introducing focused loads.

#### Stringers/Stiffeners:

Stiffeners, also known as stringers, are a portion of the boundary that the wing skin is linked to, and they prevent the skin from buckling under pressure. Axial loads resulting from bending moments in the wing are also carried by the stiffeners.

#### Skin:

The wing skin transmits in-plane shear loads into the surrounding structure and gives the wing its aerodynamic shape.

So , as for the analysis of the wing structural, we need to use CATIA to build a simplified 3D model.

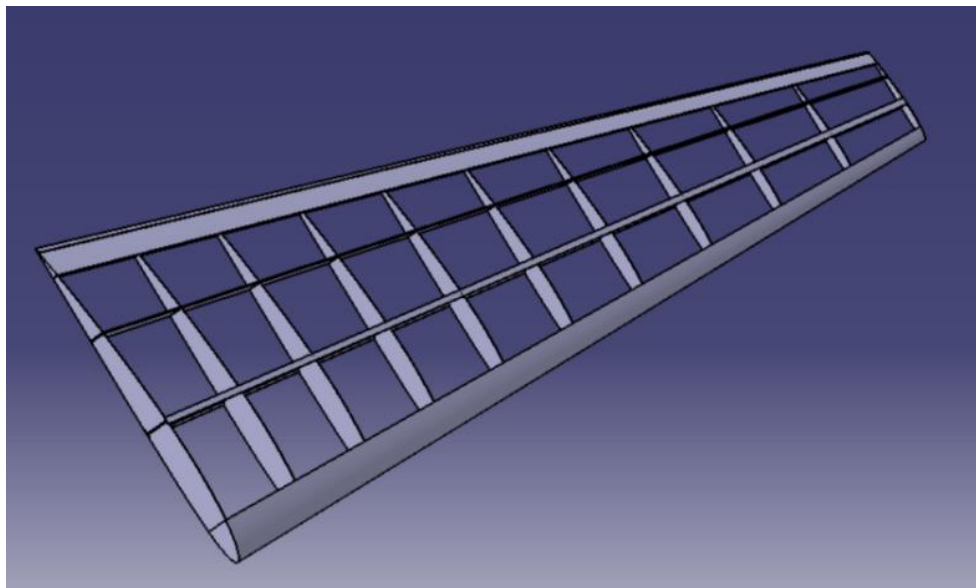


Fig 2.2 The 3D model of the wing

What is Meshing in FEA? Finite element analysis (FEA) is a mathematical representation of a physical system comprising a part/assembly, material properties and boundary conditions. In several situations, product behavior in the real-world cannot be approximated by simple hand calculations.

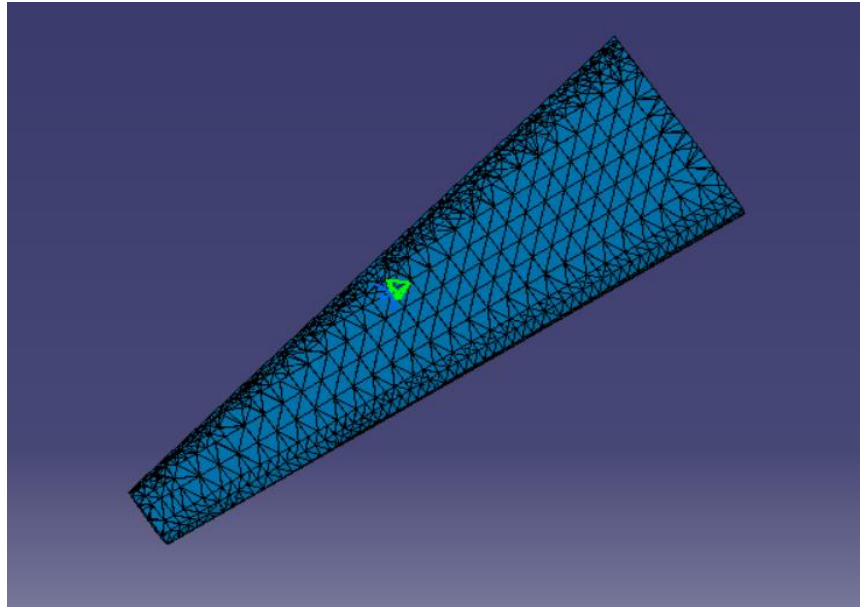


Fig 2.3 Finite Element mesh of Wing Structure

## 2.4 Boundary Condition Definition

The wings and fuselage of an aircraft are generally manufactured separately and then transported to a unified assembly plant for assembly. The Pickle Fork is used to link the wings and fuselage, as shown in Figure.

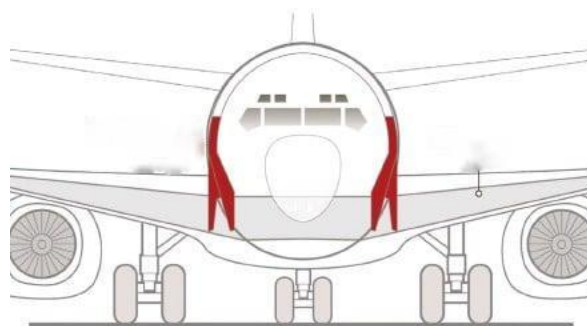


Fig 2.4 The Pickle Fork

A wing must create adequate lift equal to the maximum weight of the aircraft multiplied by the Ultimate Load Factor in addition to producing a lifting force equal to the weight of the aircraft. As a result, an aircraft weighing 12000 pounds with an ultimate load factor of 4.5 must be able to provide 54000 pounds of lift at a speed allowed by FAR standards (dive speed). The maximum lift coefficient of the wing and the corresponding stall speed determine the lowest speed below which the wing is incapable of delivering the full 54 000 lbs of lift. In reality, a V-n diagram is created, which graphically depicts the aircraft's flying envelope. In this first post, we won't go through the V-n diagram.

The distribution of the lifting force along the span of the wing is approximated once the maximum lifting force for that wing has been determined. A typical wing's lift distribution is parabolic in form, increasing from the tip to a maximum at the root.

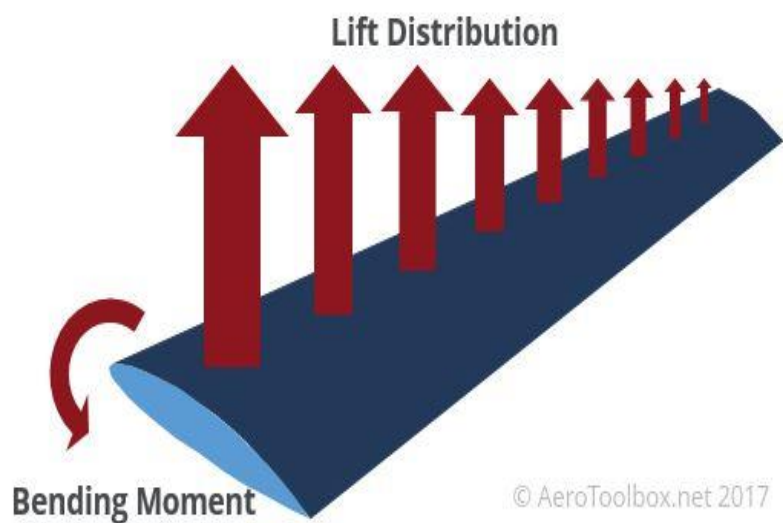


Fig 2.5 The load on the wing

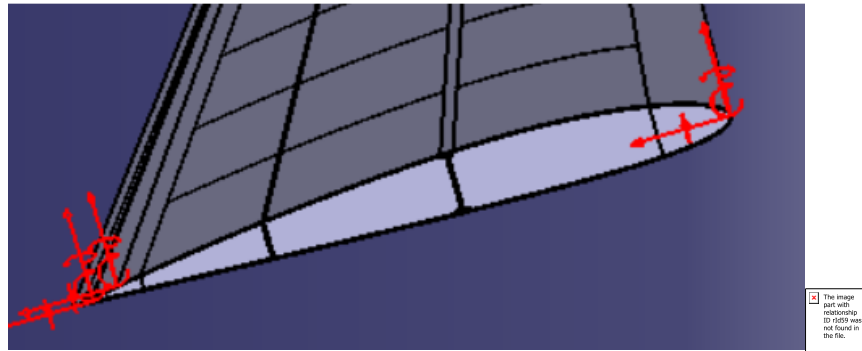


Fig 2.6 The strain of the analysis

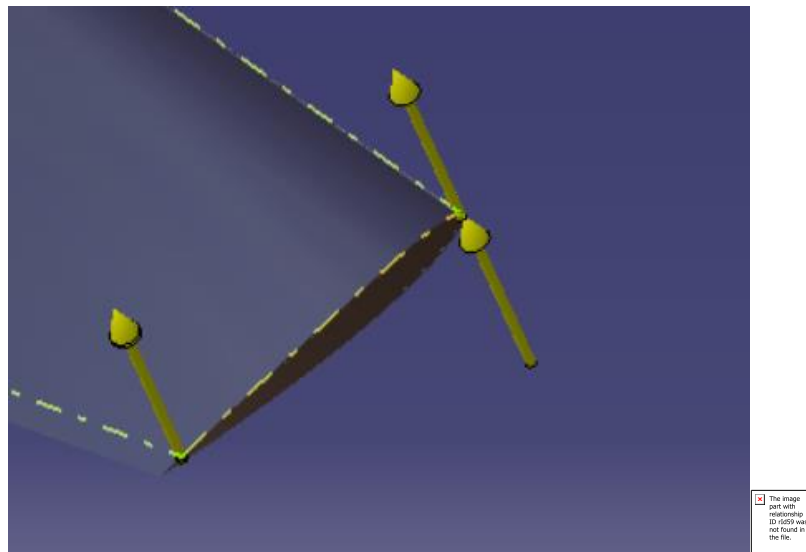


Fig 2.7 The load of the analysis

## 2.5 Finite Element Analysis of Wing Structure

When the aircraft is parked on the apron, there is no fuel remaining, and the mass only includes the weight of the aircraft wing structure. In order to simplify the calculation, the gravity is integrated into a distributed force, which is evenly distributed on the skin surface. At this time, the maximum stress on the wing is 369MPa.

There are many types of aluminum alloys used in aircraft. The aluminum alloys used in aviation aircraft structures around the world are mainly high-strength 2 series (2024, 2017, 2A12, etc.) and ultra-high-strength 7 series (7075, 7475, 7050, 7A04, etc.), and



some 5 series (5A06) , 5052, 5086, etc.) and 6 series (6061, 6082, etc.) and a small amount of other series of aluminum. The material selected for the wing in this paper is 2A12, and the yield strength of 2A12 is 390-420MPa, and the maximum stress on the wing is only 369MPa<390MPa, so the wing will not plastically deform when the aircraft is parked on the ground.

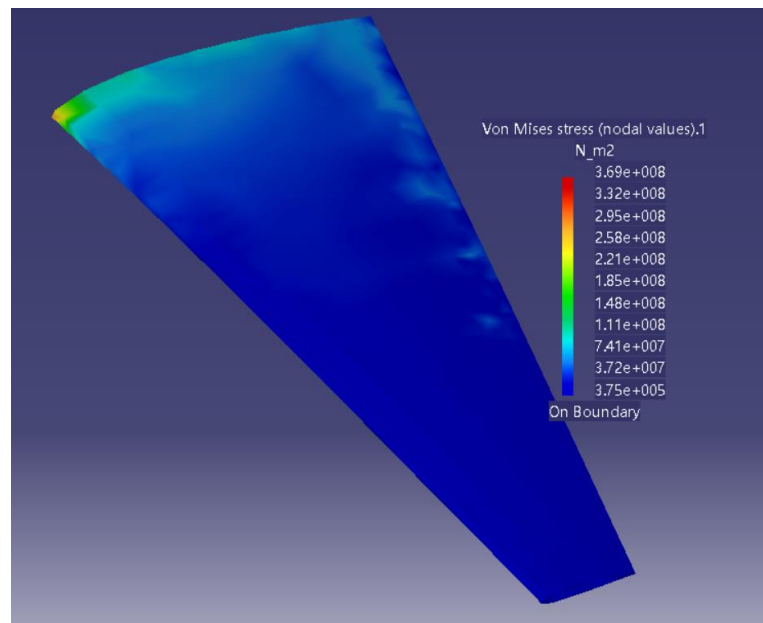


Fig2.8 The Von Mises stress

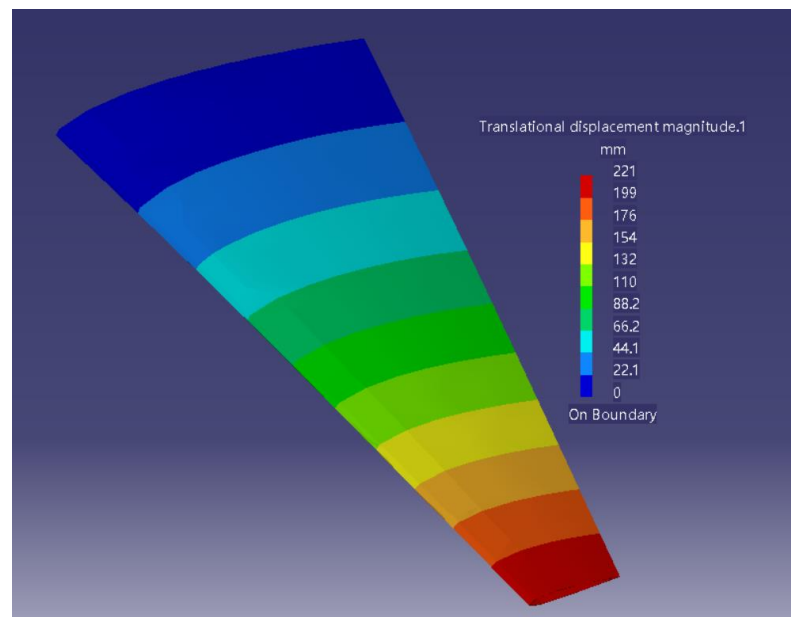


Fig2.9 The deformation

## **Conclusion to part 2**

Then, according to the size of the aircraft wing, a three-dimensional digital model of the wing is established in CATIA, and the material used in the commonly used aircraft wing is used as the material used in the wing in this article, and then the analysis module included in the CATIA software is used to consider the stress distribution of the wing under ideal conditions to ensure that the stress on the wing is within the yield strength range of the selected material.

In this part, we make sure that the wing can carry the load from Gravity, so that when parking version, the wing will be able to stay its geometry.

## GENERAL CONCLUSION

As the country vigorously promotes the development of the civil aviation industry, the development of civil aviation passenger aircraft has always been the focus of national research and development. With the needs of economic development and the development of composite materials, large and medium-sized civil airliners have become the focus of research. Under this circumstance, this paper takes Airbus A330 as the prototype, and optimizes the number of passenger seats and ride comfort to a certain extent.

The main research work in this paper is as follows:

(1) Based on the commercial airliner A330, which is already approaching maturity, relevant data such as take-off weight, geometric parameters of wings and fuselage, etc. have been selected, and the parameters have been adjusted according to the ride comfort.

(2) Using the existing initial data and related formulas, the overall size of the aircraft is calculated and the three views of the aircraft are drawn. Then, using the cabin size and the seat size and seat arrangement selected within the specified range, the layout design of the interior of the aircraft cabin is completed, and the three views of the aircraft cabin are drawn. Finally, according to the maximum take-off weight of the aircraft and the weight fraction of each part, the mass of each part of the aircraft is calculated, and the mass moment of each part is calculated in combination with the relevant center of gravity of each part.

(3) Using CATIA software to complete the 3D modeling of the structure of the aircraft wing, and using the analysis module that comes with the CATIA software to complete the static strength analysis of the wing under ideal conditions. The obtained results show that the maximum stress on the wing is within the yield strength of the selected material, so the wing meets the strength condition.

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## Appendix A

### INITIAL DATA AND SELECTED PARAMETERS

Passenger Number	240
Flight Crew Number	2
Flight Attendant or Load Master Number	8
Mass of Operational Items	3601.05 kg
Payload Mass	26400kg
Cruising Speed	870 km/h
Cruising Mach Number	0.8162
Design Altitude	12.5 km
Flight Range with Maximum Payload	10800 km
Runway Length for the Base Aerodrome	3.30 km
Engine Number	2
Thrust-to-weight Ratio in N/kg	2.6
Pressure Ratio	34.8
Accepted Bypass Ratio	5.00
Optimal Bypass Ratio	5.00
Fuel-to-weight Ratio	0.4510
Aspect Ratio	10.06
Taper Ratio	3.00
Mean Thickness Ratio	0.110
Wing Sweepback at Quarter of Chord	31°
High-lift Device Coefficient	0.930
Relative Area of Wing Extensions	0.000
Wing Airfoil Type	supercritical
Winglets	no
Spoilers	yes
Fuselage Diameter	5.60m
Fineness Ratio of the fuselage	9.00
Horizontal Tail Sweep Angle	35°
Vertical Tail Sweep Angle	45°

### CALCULATION RESULTS

Optimal Lift Coefficient in the Design Cruising Flight Point	$C_y = 0.54913$
Induce Drag Coefficient	$C_x = 0.00894$
ESTIMATION OF THE COEFFICIENT $D_m = M_{critical} - M_{cruise}$	
Cruising Mach Number	0.81619
Wave Drag Mach Number	0.82447
Calculated Parameter $D_m$	0.00828
Wing Loading in kPa (for Gross Wing Area):	
At Takeoff	5.832
At Middle of Cruising Flight	4.597
At the Beginning of Cruising Flight	5.596

Drag Coefficient of the Fuselage and Nacelles	0.00948
Drag Coefficient of the Wing and Tail Unit	0.00895
Drag Coefficient of the Airplane:	
At the Beginning of Cruising Flight	0.02999
At Middle of Cruising Flight	0.02805
Mean Lift Coefficient for the Ceiling Flight	0.54913
Mean Lift-to-drag Ratio	19.57675
Landing Lift Coefficient	1.466
Landing Lift Coefficient (at Stall Speed)	2.199
Takeoff Lift Coefficient (at Stall Speed)	1.841
Lift-off Lift Coefficient	1.344
Thrust-to-weight Ratio at the Beginning of Cruising Flight	0.449
Start Thrust-to-weight Ratio for Cruising Flight	2.268
Start Thrust-to-weight Ratio for Safe Takeoff	2.870
Design Thrust-to-weight Ratio $R_o$	3.013
Ratio $D_r = R_{cruise} / R_{takeoff}$ $D_r$	0.790

SPECIFIC FUEL CONSUMPTIONS (in kg/kN\*h):

Takeoff	35.9228
Cruising Flight	57.6607
Mean cruising for Given Range	64.2440

FUEL WEIGHT FRACTIONS:

Fuel Reserve	0.02953
Block Fuel	0.36664

WEIGHT FRACTIONS FOR PRINCIPAL ITEMS:

Wing	0.12619
Horizontal Tail	0.00932
Vertical Tail	0.00962
Landing Gear	0.03353
Power Plant	0.09014
Fuselage	0.07769
Equipment and Flight Control	0.09947
Additional Equipment	0.00695
Operational Items	0.01812
Fuel	0.39618
Payload	0.13283

Airplane Takeoff Weight  $M = 198748 \text{ kg}$

Takeoff Thrust Required of the Engine  $299.44 \text{ kN}$

Air Conditioning and Anti-icing Equipment Weight Fraction  $0.0174$

Passenger Equipment Weight Fraction (or Cargo Cabin Equipment)	0.0097
Interior Panels and Thermal/Acoustic Blanketing Weight Fraction	0.0057
Furnishing Equipment Weight Fraction	0.0101
Flight Control Weight Fraction	0.0040
Hydraulic System Weight Fraction	0.0122
Electrical Equipment Weight Fraction	0.0269
Radar Weight Fraction	0.0024
Navigation Equipment Weight Fraction	0.0036
Radio Communication Equipment Weight Fraction	0.0018
Instrument Equipment Weight Fraction	0.0042
Fuel System Weight Fraction	0.0126

Additional Equipment:

Equipment for Container Loading	0.0048
No typical Equipment Weight Fraction (Build-in Test Equipment for Fault Diagnosis, Additional Equipment of Passenger Cabin)	0.0021

TAKEOFF DISTANCE PARAMETERS

Airplane Lift-off Speed	299.80km/h
Acceleration during Takeoff Run	2.39m/s <sup>2</sup>
Airplane Takeoff Run Distance	1445m
Airborne Takeoff Distance	578m
Takeoff Distance	2024m

CONTINUED TAKEOFF DISTANCE PARAMETERS

Decision Speed	284.81 km/h
Mean Acceleration for Continued Takeoff on Wet Runway	0.36m/s <sup>2</sup>
Takeoff Run Distance for Continued Takeoff on Wet Runway	2229.30 m
Continued Takeoff Distance	2807.68m
Runway Length Required for Rejected Takeoff	2908.73m

LANDING DISTANCE PARAMETERS

Airplane Maximum Landing Weight	135644kg
Time for Descent from Flight Level till Aerodrome Traffic Circuit Flight	23.6min
Descent Distance	57.06km
Approach Speed	255.06km
Mean Vertical Speed	2.05m/s
Airborne Landing Distance	519m
Landing Speed	240.06km/h
Landing run distance	795m
Landing Distance	1314m

Runway Length Required for Regular Aerodrome  
Runway Length Required for Alternate Aerodrome

2195m  
1866m





# Appendix B

